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EVALUATING LIVELIHOOD RISKS DUE TO CHANGES IN ENVIRONMENT AND ECOLOGICAL RESOURCES OF CAN GIO MANGROVE BIOSPHERE RESERVE, HO CHI MINH CITY, VIETNAM

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ABSTRACT

Can Gio Mangrove Biosphere Reserve was recognized as a global biosphere reserve by UNESCO in 2000 with typical diverse flora and fauna of the mangroves of Vietnam and Southeast Asia. Communities in Can Gio depends mainly on natural resources for their livelihoods. Thus, any negative changes due to environmental pollution will create potential risks that directly affect the livelihoods of local residents. The research was conducted based on the interview results of 537 local residents using a structured questionnaire and 45 in-depth interviews using data of open-ended questions designed based on the 5-point Likert scale. A set of criteria was developed according to the sustainable livelihood framework of DFID (1999) to evaluate the impacts of environmental changes on livelihood risks in the study area.

This study uses weighting methodology for qualitative data and GIS methodology to identify risks levels of 13 livelihood genres affected by changes in environment ecological resources of Can Gio mangrove forest. The results show that there is a difference in the levels of livelihood risk caused by environmental changes and almost 13 types of livelihoods have very low to high risk level. As a result, there should be a risk management strategy which focuses on solutions to control hazards, exposures and vulnerability, as well as measures to protect and support livelihood resources for Can Gio local residents.

KEYWORDS: Environment, Natural Resources Degradation, Livelihood Risks & Mangrove Forest

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Original Article

1. INTRODUCTION

Can Gio mangrove forest is under pressure from several potential pollution sources (Böddeker et. al, 2020), which are mainly from urban areas, industrial zones and deep-water ports and discharged into the Soai Rap, Long Tau, Dong Tranh and Thi Vai river systems, then flowing into the sea (Thanh-Nho N et.al, 2019; Böddeker et. al, 2017). Most of the pollutants are direct domestic wastewater from urban communities; industrial wastewater from riverside industrial parks discharged directly or through undersea sewers; wastewater, waste oil and chemicals from ships; oil spill incidents of oil tankers (Thanh et. al, 2019). As a result, people's livelihoods in Can Gio have been affected dramatically due to these environmental issues, which have become increasingly worse, threatening mangrove ecosystems and marine resources. Furthermore, a number of countries are struggling with environmental problems of coastal areas (Blasco et.al, 1996; Böddeker, 2017). They threaten biodiversity; increase frequency of insect infestations and disease outbreaks; and create potential challenges to community livelihood (Jongman et.al, 2012). Additionally, they cause negative impacts on mangrove ecosystems and agroecosystems, significantly affecting the livelihoods of local people (FAO and IWMI, 2017).

Several domestic and international studies have shown that Vietnam in general and Can Gio District, in

particular, is facing the problem of water pollution (Böddeker et. al, 2017, Tran Trong Hung et. al, 2019), which can cause risks to agricultural production, aquaculture, human health and biodiversity (FAO and IWMI, 2017). Similar to most other developing countries, people in Can Gio depend on mangrove resources for their livelihoods (Thai Thanh Luom & Nguyen T. D. Phong, 2020). Any negative impacts on these resources will affect livelihood security, widening the wealth gap (Cormier-Salem, 2017). Although there are various risk evaluation studies in the field of environmental, physical-chemical-biological (ERA, 2010), risk due to environmental towards socio-economic approach in Can Gio is limited. Therefore, this study focuses on risk evaluation and analysis towards socio-economic approach based on interview results and GIS technique to detect and evaluate different risks caused by changes in the environment and mangrove resources to different livelihood types.

2. DATA AND METHODS

2.1. Data

Analytical data was taken from 600 household interviews in March 2020, which was divided into 2 phases: In the first phase, data collectors interviewed households in 6 communes and 1 town with 537 valid household interviews and an error of 2,3% including: 97 interviews in core zones, 220 interviews in buffer zones and 220 interviews in production zones. 45 in-depth interviews were conducted with village heads, officers of district level and Department of Agriculture and representatives of Can Gio Mangrove Forest Management Board for environmental and agroforestry issues. The questionnaire was designed based on the knowledge and experience of local residents and experts about the risks at present and during the past 10 years. These risks are due to changes in environment and mangrove forest resources affecting human capital, natural capital, physical capital, financial capital and social capital for 13 livelihood genres in Can Gio. Coordinates of interviewed households were identified by GPS in order to build a GIS database. GIS data inludes: Land use map, Base map and Water quality map (DONRE, 2019).

2.1. Methods

According to the risk evaluation approach of Gormley et al (2011), existing interview database and livelihood framework of DFID (1999), risks are identified and a set of criteria for evaluating risks due to changes in the environment and mangrove resources for 13 livelihood types is established including: human capital risk, natural capital risk, and physical capital risk, financial capital risk and social capital risk. (Table 1).

The criteria for identifying risks are open criteria based on interview results. Using a 5-point Likert scale ranging from 1 (no risk), 2 (low risk), 3 (medium risk), 4 (high risk), to 5 (very high risk), respondents were asked to rate the weight of each livelihood risk due to changes in environment and mangrove resources (Dufour et al, 2012; Gormley et al, 2011 and MONRE, 2019). The results were utilized to evaluate the level of risk for each livelihood because of environmental and mangrove forest resources. Data were analyzed by appropriate statistical techniques.

Livelihood risk evaluation in this research was carried out through the analysis of consequences and likelihood of risk occurrence. The basis of evaluating risks is based on the principle shown in Figure 1 (Gormley et al, 2011). According to it, the low-risk category is considered acceptable without affecting livelihoods. In contrast, livelihoods that having high risk require strict risk management. Regrading medium-rik livelihoods, they demand risk evaluation to better understand all risk aspects in order to propose solutions to risk reduction (Gormley et al, 2011; Suter, 2007).

Table 1: The Livelihood Indexes to Evaluate the Impact of Environmental Change

Standard/ Capital	Criteria/ Components	Indexes	Evaluation aspects
Human capital	*Demography*	Family size; Number of employees in the family	Exposure
	Health	Family health status	Vulnerability
	Education	The highest level of study of family members	Vulnerability
	Skill	Technical level of farming and exploitation	Exposure
	Information	Level of grasping information about the State policies and regulations related to farming and exploitation	Vulnerability
		Level of grasping information about natural disasters and diseases	Vulnerability
		Level of grasping information about market demand	Vulnerability
		Level of grasping information about prices	Vulnerability
	Awareness	Awareness of local natural environmental and socio-economic changes	Hazard
		Awareness of livelihood risks caused by environmental change	Hazard
		Awareness of livelihood risks due to climate change	Hazard
Natural capital	*Land*	Decline in residential land	Hazard
		Decline in arable land	Hazard
		Decline in land for rent	Hazard
	Natural resources	Forest degradation	Hazard
		Marine resource degradation	Hazard
Physical capital	*Housing*	Types of houses	Exposure
	Living facilities	Possession of motorbikes, refrigerators, televisions, washing machines, air conditioners, etc.	Exposure
	Production tools	Possession of canoes, motorboats, pumps, generators, etc.	Exposure
Financial capital	*Income*	Main livelihood income	Vulnerability
		Average monthly household income (for all livelihoods)	Vulnerability
	Capital	Available capital for production	Vulnerability
	Credit	Ability to mobilize State, private and acquaintance's credit	Exposure
Social capital	Social *participation*	Participation in local organizations and unions	Exposure
	Social support	Support from the authorities	Exposure
		Support from family, acquaintances, neighbors	Exposure
	Work cooperation	Cooperation with traders, agents, companies	Exposure
Source: Result analyzed from the field survey, interview households base on DFID (1999).			

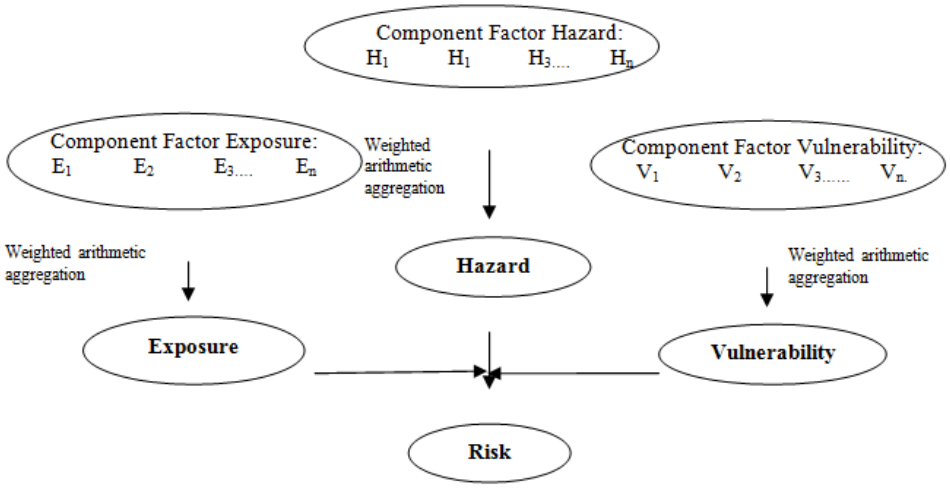

Figure 1: Aggregating Single Factors to Risk Components of Livelihood Types in Can Gio

A set of criteria for evaluating livelihood risks due to environmental change, mangrove resources degradation was established based on the Environmental Status Report of Can Gio District in 2020. Criteria (Table 2) were also designed in collaboration with experts from Can Gio Mangrove Forest Management Board and environmental management experts from district and commune level to consider the impacts of livelihood risks by environmental change and mangrove resources degradation.

Table 2: Criteria for Evaluating Livelihood Risks due to Environmental Changes and Mangrove Resources Degradation

Factors Affected by Environmental Change and Mangrove Resources Degradation	Risk Evaluation based on Standard/Capital for Livelihood Types				
	Human Capital	Natural Capital	Physical Capital	Financial Capital	Social Capital
1. Water quality	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
2. Quality of natural food sources	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
3. Aquatic animal diversity	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
4. Terrestrial animal diversity	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
5. Forest diversity	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
6. Forest cover level	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
7. Environment of alluvial ground and coastal area	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}	R_{1-5}
Risk rating scale: 0 —0.2= very low (R_1); > 0.2 — 0.4= low; (R_2); > 0.4 — 0.6= medium (R_3); > 0.6 — 0.8= high (R_4); > 0.8 — 1= very high (R_5)					
Source: Result analyzed from the household survey by authors					

Proposed 7 criteria (MONRE, 2019) to evaluate risks due to changes in environment and natural resources are as follows: water quality; quality of natural food sources; aquatic animal diversity; terrestrial animal diversity; forest diversity; forest cover level; environment of alluvial ground and coastal area

The proposed risk rating scale is referred to Hagenlocher (2018), Gormley (2011) and Dufour (2012) so as to change the ratio from absolute value to relative value: 1. Very low, 2. Low, 3. Medium, 4. High, 5. Very high and the weights are calculated according to Equation 1 and 2 as follows:.

Equation 1: Aggregating single indicators to a risk component (Hagenlocher, 2018)

$$CI = \frac{(I_1 * w_1 + I_2 * w_1 + \cdots I_n * w_n}{\sum_1^n w} \quad (1)$$

with I = single indicators; w_n = weighting of single indicators

Equation 2: Aggregation of risk components

$$Risk = \frac{(Hazard * w_H) + (Vulnerability * w_V) + (Exposure * w_E)}{w_H + w_H + w_H} \quad (2)$$

with w_H = weighting of hazard indicators; w_V = weighting of vulnerability indicators; w_E = weighting of exposure indicators.

In addition, the study uses the IDW interpolation method (Watson and Philip, 1985) to determine the spatial distribution of livelihood vulnerability values in the study area by combining linear weighted sets of the interview sample points. Equation 3: Inverse distance weight formula

$$x^* = \frac{w_1.x_1 + w_2.x_2 + w_3.x_3 + \cdots + w_n.x_n}{w_1 + w_2 + w_3 + \cdots + w_n} \quad (3)$$

Where x^* is unknown value at a location to be determined, w is the weight and x is known point value

3. DISCUSSIONS

3.1. Evaluating Risk Factors Affecting 5 Sources of Livelihood Capital for Different Livelihood types in Can Gio District due to Environmental and Mangrove Resources Changes

By identifying indexes and evaluating risks from 537 household surveys, 45 in-depth interviews and secondary data, 13 types of livelihoods in Can Gio Mangrove Biosphere Reserve were selected to evaluate the level of risk due to environmental and mangrove resources changes, including: shrimp farming, pisciculture, fish cage farming, scallop and snail farming, lagoon aquaculture, river-bed fishing, offshore and nearshore fishing, swiftlet farming, salt production, rice cultivation, oyster farming, crab farming and orchard farming. Index values of risk components are standardized on a scale of 0 to 1, and aggregated into an overall risk value (arithmetic synthesis method) for three risk components such as hazard, exposure and vulnerability (Table 3). Table 4 shows risk factors affecting 5 capital sources for 13 livelihood forms in Can Gio District due to changes in environment and mangrove resources according to a 5-level risk rating scale as follows: 0 – 0.2 = very low (VL); > 0.2 – 0.4= low (L); > 0.4 – 0.6= medium (M); > 0.6 – 0.8= high (H); > 0.8 – 1= very high (VH).

Table 3: Average Weight of Risk Components of Livelihood types by Environmental and Mangrove Resources Changes in Can Gio

No	Livelihood Types	Average Weight of Risk Components index			
		Hazard	Exposure	Vulnerability	Average Overall Risk
1	Shrimp farming	0,69	0,65	0,58	0,64
2	Crab farming	0,6	0,51	0,56	0,56
3	Pisciculture	0,52	0,67	0,63	0,61
4	Fish cage farming	0,61	0,59	0,48	0,56
5	Scallop and snail farming	0,45	0,51	0,48	0,48
6	Lagoon aquaculture (particulary shrimp)	0,49	0,35	0,48	0,44
7	Oyster farming	0,47	0,51	0,44	0,47
8	River-bed fishing	0,62	0,62	0,61	0,62

Table 3: Contd,.					
9	Offshore and nearshore fishing	0,66	0,58	0,59	0,61
10	Salt production	0,11	0,22	0,19	0,17
11	Rice cultivation	0,52	0,63	0,58	0,58
12	Orchard farming	0,34	0,41	0,42	0,39
13	Swiftlet farming	0,24	0,25	0,21	0,23
Source: Result analyzed from the household survey by authors					

Table 4: Evaluating Risk Factors Affecting 5 Sources of Livelihood capital for 13 Livelihood types in Can Gio District due to Environmental and Mangrove Resources Changes

Risk Components index of Livelihood types for Five Capitals		Risk Factors due to Environmental and Mangrove Resources Changes						
		Water Quality	Quality of Natural Food Sources	Aquatic Animal Diversity	Terrestrial Animal Diversity	Forest Diversity	Forest Cover Level	Environment of Alluvial Ground and Coastal Area
Shrimp farming	Human capital	*M*	*H*	*M*	*H*	*M*	*M*	*M*
	Natural capital	*H*	*H*	*H*	*VL*	*M*	*M*	*H*
	Physical capital	*M*	*VL*	*M*	*VL*	*VL*	*VL*	*L*
	Financial capital	*H*	*VL*	*VL*	*VL*	*M*	*VL*	*L*
	Social capital	*H*	*VL*	*VL*	*VL*	*L*	*L*	*M*
Crab farming	Human capital	*M*	*M*	*M*	*M*	*M*	*M*	*M*
	Natural capital	*M*	*M*	*H*	*L*	*L*	*L*	*M*
	Physical capital	*M*	*M*	*L*	*L*	*L*	*M*	*L*
	Financial capital	*M*	*M*	*H*	*H*	*H*	*H*	*H*
	Social capital	*M*	*L*	*M*	*L*	*L*	*M*	*M*
Pisciculture	Human capital	*H*	*M*	*H*	*H*	*H*	*M*	*H*
	Natural capital	*H*	*H*	*H*	*H*	*H*	*M*	*H*
	Physical capital	*M*	*M*	*M*	*L*	*M*	*L*	*M*
	Financial capital	*H*	*H*	*M*	*H*	*H*	*M*	*H*
	Social capital	*L*	*L*	*L*	*M*	*M*	*M*	*M*
Fish cage farming	Human capital	*L*	*L*	*L*	*M*	*M*	*M*	*M*
	Natural capital	*VL*	*L*	*L*	*VL*	*L*	*L*	*L*
	Physical capital	*M*	*M*	*M*	*L*	*L*	*L*	*M*
	Financial capital	*M*	*M*	*M*	*M*	*M*	*VL*	*M*
	Social capital	*M*	*L*	*L*	*L*	*M*	*M*	*M*

Scallop and snail farming	Human capital	*H*	*H*	*H*	*L*	*H*	*H*	*H*
	Natural capital	*H*	*H*	*H*	*M*	*M*	*M*	*M*
	Physical capital	*M*	*VL*	*L*	*L*	*L*	*L*	*L*
	Financial capital	*H*	*L*	*L*	*L*	*L*	*L*	*L*
	Social capital	*M*	*M*	*L*	*L*	*L*	*L*	*L*
Lagoon aquaculture	Human capital	*H*	*H*	*VH*	*L*	*H*	*H*	*H*
	Natural capital	*H*	*H*	*H*	*M*	*H*	*H*	*H*
	Physical capital	*M*	*L*	*L*	*L*	*L*	*VL*	*L*
	Financial capital	*M*	*M*	*VL*	*L*	*L*	*M*	*M*
	Social capital	*M*	*L*	*VL*	*L*	*L*	*VL*	*L*
River-bed fishing	Human capital	*H*	*H*	*VH*	*L*	*M*	*M*	*H*
	Natural capital	*H*	*H*	*VH*	*M*	*H*	*H*	*H*
	Physical capital	*M*	*L*	*H*	*M*	*L*	*L*	*M*
	Financial capital	*M*	*M*	*VL*	*L*	*L*	*L*	*M*
	Social capital	*M*	*L*	*M*	*L*	*M*	*M*	*M*
Offshore and nearshore fishing	Human capital	*H*	*H*	*H*	*TB*	*TB*	*T*	*H*
	Natural capital	*H*	*H*	*H*	*L*	*H*	*H*	*H*
	Physical capital	*H*	*H*	*L*	*L*	*L*	*M*	*M*
	Financial capital	*H*	*H*	*H*	*L*	*L*	*L*	*M*
	Social capital	*H*	*L*	*H*	*L*	*L*	*L*	*M*
Swiftlet farming	Human capital	*VL*	*VL*	*VL*	*M*	*M*	*M*	*M*
	Natural capital	*M*	*H*	*L*	*L*	*M*	*M*	*M*
	Physical capital	*L*	*L*	*L*	*L*	*M*	*M*	*L*
	Financial capital	*H*	*M*	*VL*	*L*	*M*	*M*	*L*
	Social capital	*M*	*M*	*VL*	*L*	*L*	*M*	*L*
Salt production	Human capital	*H*	*L*	*VL*	*VL*	*VL*	*VL*	*L*
	Natural capital	*M*	*VL*	*VL*	*VL*	*L*	*L*	*M*
	Physical capital	*M*	*VL*	*VL*	*VL*	*L*	*L*	*L*

	Financial capital	*L*	*VL*	*VL*	*VL*	*L*	*L*	*L*
	Social capital	*L*	*VL*	*VL*	*VL*	*L*	*L*	*L*
Oyster farming	Human capital	*M*	*M*	*VL*	*M*	*L*	*M*	*M*
	Natural capital	*M*	*M*	*M*	*L*	*L*	*L*	*M*
	Physical capital	*M*	*M*	*L*	*L*	*L*	*M*	*L*
	Financial capital	*H*	*M*	*L*	*L*	*L*	*L*	*M*
	Social capital	*L*	*L*	*M*	*L*	*L*	*L*	*LT*
Rice cultivation	Human capital	*H*	*L*	*L*	*L*	*M*	*M*	*M*
	Natural capital	*M*	*L*	*M*	*L*	*L*	*L*	*L*
	Physical capital	*M*	*L*	*L*	*L*	*L*	*L*	*L*
	Financial capital	*H*	*L*	*M*	*M*	*M*	*L*	*M*
	Social capital	*M*	*M*	*M*	*L*	*L*	*M*	*M*
Orchard farming	Human capital	*M*	*VL*	*VL*	*L*	*M*	*M*	*L*
	Natural capital	*M*	*L*	*L*	*L*	*L*	*L*	*L*
	Physical capital	*M*	*L*	*L*	*M*	*L*	*L*	*L*
	Financial capital	*H*	*L*	*M*	*M*	*L*	*L*	*L*
	Social capital	*M*	*L*	*L*	*M*	*L*	*L*	*L*
Source: Result analyzed from the household survey by authors								

According to the results in Tables 3 and 4, risk rating due to changes in environment and resources for households whose livelihood is shrimp farming is high (0.64). The main risk factor for this livelihood is the quality of untreated source water led into shrimp ponds which can cause shrimp deaths and have effects on natural capital and financial capital. In addition, the study results show that factors affecting the natural environment and ecological diversity of mangroves also have a great impact on the stability of this livelihood.

Crab farming is considered as a complementary model in order to diversify livelihoods for residents in brackish and saline water zones, take advantage of the potential of water surface, increase income and diminish the risks of shrimp farming in Can Gio District. Risk rating for crab farming (Table 3 and Table 4) due to environmental and mangrove resources change is medium (0.56). This livelihood is significantly suitable for local people because high technology is not required, crab seeds are easy to buy, soil improvement is not much.

Pisciculture in Can Gio is also a popular livelihood, but the scale and areas are not large. Table 3 and Table 4 show that the risk level of this livelihood is also high (0.61) and the risk indexes are similar to shrimp farming because of polluted source water, decline in natural food sources and dependence on weather changes.

Table 3 and Table 4 indicate that the livelihood model of fish cage farming has a medium risk level (0.56). This form of livelihood is concentrated in some communes such as An Thoi Dong, Ly Nhon, Tam Thon Hiep and Thanh An Communes. In these areas, there is an extensive river and canal system including Nha Be River, Long Tau River and Dong Tranh River to provide abundant natural food (natural capital).

Livelihood risk for scallop and snail farming is at medium level (0.48). This model is concentrated in Can Thanh, Long Hoa, Ly Nhon and Thanh An Communes, where people can take advantage of lagoons, natural river and coastal alluvial areas, whose environment is less affected by pollution. The risk factors for this model are related to water quality of ponds, lagoons and farming areas (natural capital) and financial capital used to invest in improving the water source to ensure the pond environment quality.

Aquaculture in lagoons is mainly concentrated in the core and buffer zones of Thanh An, Tam Thon Hiep, An Thoi Dong, and Long Hoa Communes. Risk level of this livelihood is medium (0.44) and primary risk factors are quality of water sources, natural food sources, forest cover level and aquatic animal diversity.

River-bed fishing has a high risk level (0.62). This livelihood is concentrated mainly in the core and buffer zones, such as in Long Hoa, Ly Nhon and Thanh An Communes where aquatic species often inhabit and reproduce. Due to overfishing, the decline in the number of aquatic species poses high risks to this type of livelihood. In addition, extreme weather events like strong wind, heavy rain and storms also cause high risks to natural, human and financial capital.

Offshore and nearshore fishing is one of the traditional livelihoods of residents in Can Gio District. However, the risk level for this livelihood is high (0.61) due to the quality of water and natural food sources and impacts from natural disasters and extreme weather events on offshore and nearshore fishing activities. Moreover, although it requires relatively large initial investment capital, the risk level is high, particularly the possibility of substantial amounts of property and human resources loss.

Swiftlet farming has developed rapidly in the last 10 years. It is concentrated in Tam Thon Hiep, An Thoi Dong, Ly Nhon, and Long Hoa Communes and some other areas in the district. According to Table 3 and Table 4, the risk level of this livelihood is still low (0.23). The risks to this profession include relatively high initial financial investment, followed by physical, natural and social capital.

Salt production is the traditional livelihood of local people in Can Gio District. It is concentrated mainly in Ly Nhon, Long Hoa and a little An Thoi Dong Commune. Based on the results in Table 3 and Table 4, the risk level of this livelihood is very low (0.17). The primary risk factor for salt production is water quality. Additionally, human, natural and physical capital also affect this livelihood.

Oyster farming is a common livelihood in Can Gio, which has an interlacing river system providing favorable conditions for farming many valuable commercial seafood species including oysters. They are one of the main species that are cultivated popularly in Can Gio particularly on the rivers of Dong Tranh, Long Hoa, etc. Table 3 and Table 4 show that this livelihood has a medium risk level (0.47) with main risk factors related to the quality of water and natural food sources.

Rice cultivation has become a minor production in Can Gio District with the current rice-growing area at 181,5 ha (0.3% of agricultural land) (DONRE, 2019). The risk evaluation result in Table 3 shows that the risk level of this livelihood is relatively high (0.58). The risk factors include saline intrusion, unstable weather conditions causing

difficulties for farming, economic inefficiency due to high production and labor costs (human and financial capital) leading to farmers' tendency to alter to aquaculture (Table 4).

Orchards in Can Gio are concentrated in the communes of Long Hoa, Binh Khanh and Can Thanh Town with the main crops having good quality such as mangoes, custard apples, apples and longans. The risk evaluation result due to changes in the environment and mangrove resources is at a low level of 0.39 (Table 3). The risk factors for this form of livelihood are contaminated soil by alum and lack of fresh water in the dry season. This livelihood requires financial, human and natural capitals to diminish environmental risks (Table 4).

3.2. Using IDW Method to Determine the Risk Spatial Distribution for Livelihoods in Can Gio Biosphere Reserve

The study combines livelihood risk weighting results of the 3 components including hazard, exposure, vulnerability based on the analysis of 537 household surveys and IDW interpolation results to determine the spatial risk distribution for study livelihoods in Can Gio mangrove forest in 3 functional zones, namely core zone, buffer zone and transition zone.

IDW interpolation results in Figure 2 show that the livelihood risk levels (0.41-0.61) due to environmental changes and degraded mangrove resources in the core zone, buffer zone, the northern area of transitional zone and Can Thanh Town are ranging from medium to relatively high. Risk factors for livelihoods in these zones include increasing contaminated water by organic compounds and heavy metal (Böddeker, 2020; Tran Trong Hung et. al, 2019) as well as the decline in biodiversity of flora and fauna under the forest canopy (Thanh-Nho N et.al, 2019; Böddeker, 2017). Regarding the transitional zone, because it is outside the core and buffer zones, the livelihood risk levels due to the biodiversity loss of mangrove ecological resources are very low (0.0-0.2). However, there is an impact of environmental pollution due to aquaculture activities but it is not significant because people are aware of the problem of environmental pollution (Thai Thanh Luom & Nguyen T.D. Phong, 2020)

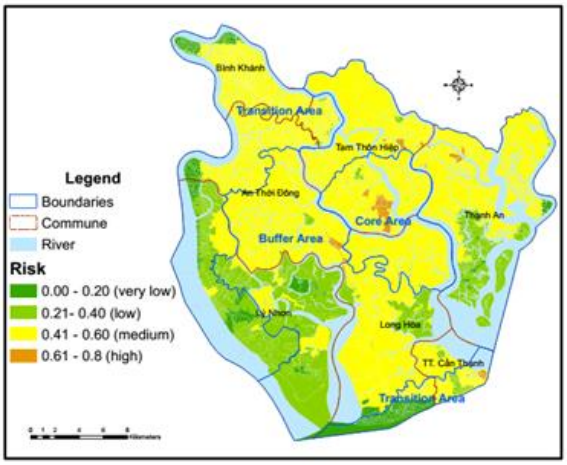

Figure 2: Aggregated Livelihood Risk Index of Can Gio Mangrove Biosphere Reserve, Ho Chi Minh City, Vietnam Source: Result Interpolated from IDW Method.

4. CONCLUSIONS AND SUGGESTIONS

The risk level for 13 livelihood types affected by environmental and mangrove resources change has been evaluated in the study. Evaluated risk factors are related to water quality, quality of natural food sources, aquatic animal diversity, terrestrial animal diversity, forest diversity, forest cover level and coastal alluvial environment. By referring to DFID

livelihood indexes, the set of vulnerability evaluation criteria was developed by the research team including 5 components (natural capital, financial capital, human capital, social capital and physical capital).

In addition, among all livelihoods affected by changes in the environment and mangrove resources, 30.7% of them having a high level of risk (Shrimp farming, Pisciculture, river-bed fishing, offshore and nearshore fishing), 46.1% of them having a medium risk level (Crab farming, Fish cage farming, scallop and snail farming, lagoon aquaculture, rice cultivation), 15.3% are low-risk livelihoods (orchard and swiftlet farming) and 7.9% of livelihood types having a very low risk level (salt production). The results are considered acceptable in the current environmental conditions of Can Gio District. Forms of livelihoods with very low and high risk levels need attention to better understand the impacts in order to come up with solutions to reduce risks. Therefore, Can Gio District needs to develop a risk management strategy, focusing on solutions to control hazards, exposures and vulnerability as well as measures to protect and support livelihood resources.

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